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IDENTIFICATION OF PEREGRINE FALCONS USING A COMPUTERIZED CLASSIFICATION SYSTEM OF TOE-SCALE PATTERN ANALYSIS

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ABSTRACT.—Individual Peregrine Falcons (*Falco peregrinus*) may be identified by visually comparing their toe-scale patterns. However, these comparisons are tedious when dealing with large numbers of birds. We developed a computerized classification system to facilitate the identification process. The classification system was based on the analysis of photographs of the dorsal surface of the third toes of both feet, and on the formulation of an alphanumeric code that distinguished right from left feet, and single from double scales of 90 Peregrine Falcons (*F. p. anatum*). Each code was entered into a computerized filing program, and toe-scale patterns were classified by similarities, dividing them into groups. The system was tested by randomly selecting photographs on file, generating a code by established criteria and matching the code with the computerized file code. The system allowed quick differentiation of individual Peregrine Falcons from a large number of catalogued Peregrine Falcons.

Identificación de *Falco peregrinus* usando un sistema de clasificación computarizado de análisis de patrones de medida de dedos

RESUMEN.—Individuos de *Falco peregrinus* pueden ser identificados visualmente comparando sus patrones de medidas de dedos. Sin embargo, estas comparaciones son tediosas cuando se trata de un gran número de aves. Desarrollamos un sistema de clasificación computarizada para facilitar el proceso de identificación. El sistema está basado en el análisis de fotografías de la superficie dorsal del tercer dedo de ambos pies y sobre la formulación de un código alfanumérico que distingue el pie derecho del izquierdo, y escalas sencillas de dobles de 90 *F. p. anatum*. Cada código fue ingresado a un programa computacional y el patrón de medidas del dedo fue clasificado por similaridades, dividiendolos en grupos. El sistema fue probado seleccionando azarosamente fotografías de un archivo, generando un código con criterio establecido y asociando éste con el código del archivo computacional. El sistema determina rápidamente la diferenciación de individuos de *F. peregrinus* de un gran número de ejemplares catalogados.

[Traducción de Ivan Lazo]

Identification of individual raptors is important to document ownership, and could be valuable to trace movements or study population dynamics. Methods to mark birds include leg banding, attachment of wing-markers, and tattooing (Beyerbach 1980, Havelka 1983). These methods and their shortcomings have been described in detail elsewhere.

The potential to develop an unalterable, safe means of permanent identification for raptors as suggested by others deserves further investigation. The presence of unique, unchanging scale patterns on the feet of various bird species that cannot be altered or removed without the risk of severe foot damage has been documented and discussed (Clark 1972, 1973, 1974, Beyerbach 1980, Havelka 1983, Stauber 1984, 1985, Grier 1986). These patterns may be easily differentiated, and therefore, may be used for individual identification.

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Figure 1. Photograph of the middle toe (#3) of a Peregrine Falcon showing the toe-scale pattern.

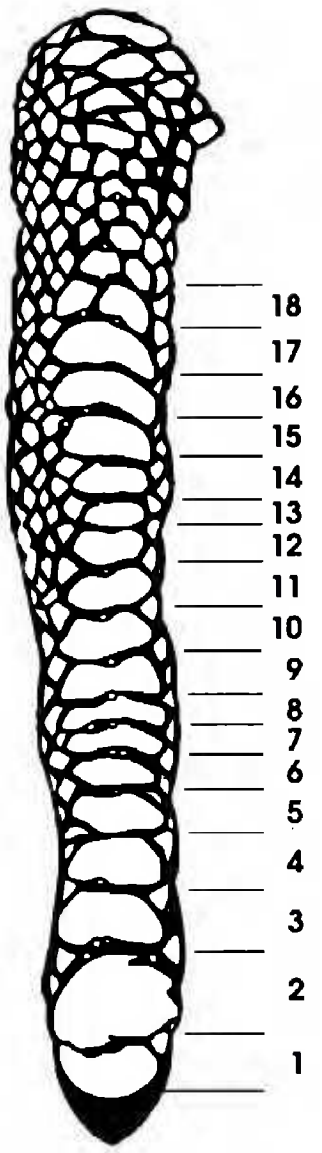

Figure 2. Hand tracing of the middle toe (#3) in the photograph shown in Fig. 1. Rows of scales are numbered sequentially counting proximally from the talon.

METHODS

Birds used for this study were Peregrine Falcons (*F. p. anatum*) housed at the Peregrine Fund, Inc., Boise, ID, U.S.A. Photographs were taken using a 35 mm single lens reflex camera, a standard 50 mm lens, and a 2× teleconverter. Because the birds were photographed indoors in incandescent and natural light, a strobe was used to ensure adequate exposure. Black-and-white film (ASA 125) was exposed at f5.6 and 1/1000 second. The dorsal surfaces of the middle digits (#3) of both feet were stained with a non-toxic iodine solution (Betadine Solution, Purdue Frederick, Norwalk, CT) to enhance the scale perimeters, making the grooves between scales more pronounced. The feet were positioned so that photographs could be taken perpendicular to the dorsal surface. The lens was focused as close (ca. 40 cm) to the foot as possible. The middle digit was extended to reduce errors in perception of angle due to curling of the toe. During photography the toe was placed on an identification grid marked in 2.54 × 2.54 mm squares, and showing the bird's U.S. Fish and Wildlife Service band number. The grid pattern enabled determination of photographic angle and absolute size. Both feet were photographed.

Black-and-white glossy prints (12.70 × 17.78 cm) were prepared from the negatives (Fig. 1). Prints were labeled with the band number, right or left foot, species, date, sex and age of the bird.

Each scale was labeled in sequence counting proximally from the talon (Fig. 2). The identification grid was used to determine right or left foot, and scales were labeled as single or double. A scale was characterized as "double" when it met one or more of the following criteria: (a) clear division of the scale into 2 parts (Fig. 3A); (b) both scales being at least partly within boundaries determined by imaginary lines drawn from the widest aspects of the scale above to the scale below (Fig. 3B); (c) the smaller scale of the "double" not having a "matching" scale on the opposite side of the larger scale (Fig. 3C); or (d) the double scale separating the scale above from the scale below by a distance greater than the usual distance between scales (with "point" contact of the above and below scales being acceptable) (Fig. 3D).

A sequence of single-digit numbers corresponding to the series of scales was constructed. Single scales were assigned the number 4, while double scales were given the number 8. These numbers were chosen because of ease in code sequences. Code sequences ended with the last identifiable scale (a single or an unambiguous double).

Each code sequence was based on the scale pattern of one middle toe. Using patterns from both feet doubled the

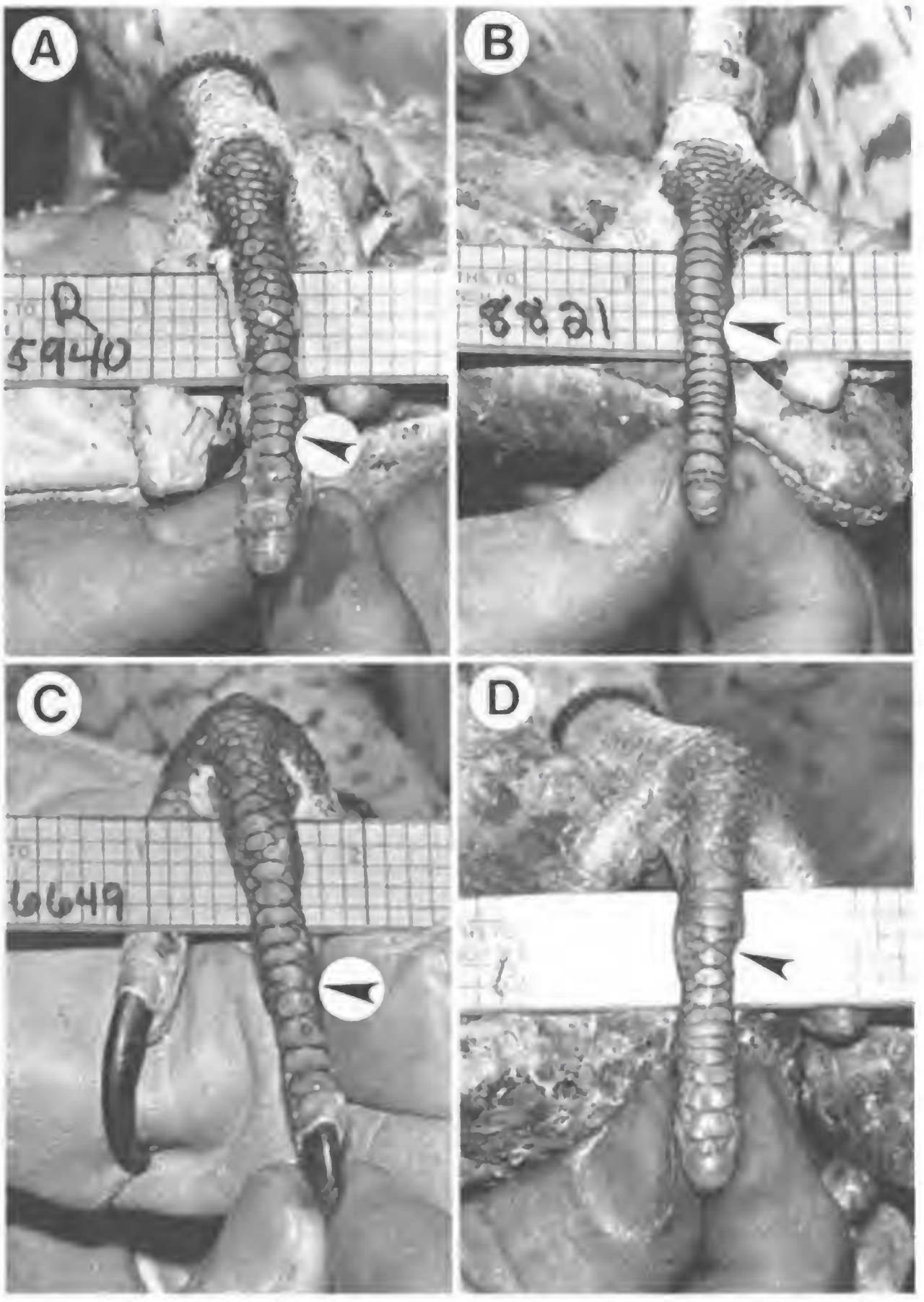

Figure 3. Criteria used to distinguish double from single scales: 3A. Clear division of the scale into 2 parts (arrow). 3B. Both scales (arrow) being at least partly within boundaries determined by imaginary lines drawn from the widest aspects of the scale above to the scale below. 3C. The smaller scale of the "double" not having a "matching" scale on the opposite side of the larger scale (arrow). 3D. The double scale (arrow) separating the scale above from the scale below by a distance greater than the usual distance between scales (with "point" contact of the above and below scales being acceptable).

available information for identification of falcons. For the filing program to use information from both feet simultaneously, right and left pattern codes were combined to create a single identification code for each falcon. Pattern codes for each toe were printed with the code from the right toe above the code for the left:

R .4.4.4.4.4.8.4.4.4.4.8.8.4.8.4.4.
L .4.4.4.4.8.4.4.4.4.4.8.4.8.4.4.4.4.4.

A code sequence combining right and left, and corresponding to each row of scales was constructed. When a "4" was over a "4," a "4" was entered. When a "4" was over an "8," a "5" was entered. When an "8" was over a "4," a "7" was entered. When an "8" was over an "8," an "8" was entered. The new code sequence ended with the last row to be characterized for both feet. The code sequence corresponding to the two patterns shown previously would be:

.4.4.4.4.5.7.4.4.4.4.8.7.5.7.4.4.

Codes were recorded in a database program (Q&A, Symantec, Cupertino, CA), and compared in order to group patterns based on the presence and location of double scales. Categorization into groups of identical codes reduced the number of prints to be used in the final matching process. In the final matching process the "suspect" print was visually compared with other prints in the same pattern group to find the "true" match.

RESULTS

Prints had from 15–20 discernible scales on the dorsal surface of each middle toe. Of 90 falcons, 75 had codes that were unique. The remaining codes had either one duplication (six groups of two identical codes), or two (one group of three identical codes). When this system was used by evaluators with no prior experience in toe-scale pattern analysis, the evaluators were successful in encoding and classifying patterns. They then easily differentiated "suspect" prints from others with identical codes by visual comparisons.

DISCUSSION

The uniqueness of toe-scale patterns in individual birds of various species has been well documented (Clark 1972, 1973, 1974, Beyerbach 1980, Havelka 1983, Stauber 1984, 1985, Grier 1986), and the potential to use this information to develop an identification system for Peregrine Falcons (or other birds) has been discussed. A major obstacle in adopting the toe-scale identification system has been the lack of a "user friendly" method allowing rapid screening of the scale pattern of one bird against numerous patterns of other birds.

There are distinct advantages in computerizing an analysis system. Large numbers of digitized prints including information about many birds can be stored in an organized, systematic manner. Time and labor spent matching a "suspect" bird's code with a print code on file can be reduced. Files or print codes can be transmitted to distant locations in a short time. Pattern characteristics can be sorted and compared to look for trends among species, subspecies or close relatives.

The primary objective of this study was to develop a computerized classification system of toe-scale patterns that could be used for rapid (initial) screening of any Peregrine Falcon's "footprint" against any number of catalogued "footprints" from other Peregrine Falcons coded by the system. The availability of 90 Peregrine Falcons from the Peregrine Fund, Inc., Boise, ID, U.S.A. was particularly welcome, since they represented a large sample size of one subspecies. Assuming there would be less variation within a subspecies than between different subspecies, a code system based on footprint variation from these birds would be a good test to validate the reliability of the system. Analysis of the toe-scale pattern of the third toe (left and right foot) from each bird resulted in generating a code where code duplication was minimal. It is felt that the results of this study provide baseline information of great utility in developing reliable identification systems for birds with unique toe-scale patterns. If this system is used with other available data (i.e., juvenile/adult, sex, weight) about individual birds, a reliable method of permanent, non-invasive, and unalterable identification of individual Peregrine Falcons could become available.

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